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The FRUGAL Science Teacher

STRATEGIES AND ACTIVITIES

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The FRUGAL Science Teacher

STRATEGIES AND ACTIVITIES

Linda Froschauer, editor

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National Science Teachers Association

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Preface

by Linda Froschauer

frugal *(froo'gal) adj. Practicing or marked by economy, as in the expenditure of money or the use of material resources. See synonym at* sparing. *2. Costing little; inexpensive.*

—The American Heritage Dictionary

Frugality practically defines how we as teachers approach provisioning our classrooms. (I half expected to see a picture of a science teacher next to the entry!) We cleverly create learning opportunities with limited resources and have amazing aptitudes for stretching shrinking funds and doing more with limited resources. Still, we find ourselves augmenting school and district funds with our own dollars, digging into our own pockets to purchase equipment and other essentials. A quick web search suggests that K–12 teachers spend between $475 and $1,500—per year—on classroom materials. And we do this willingly because we know it makes a difference in our students' learning.

In an issue of *Science Scope* devoted to limited classroom resources, editor Inez Liftig expressed concern about giving tacit approval to the expectations that teachers should spend their own money to outfit their classrooms: "I wanted to be very sure that we did not send the wrong message about whether or not science teachers should spend their own money to support instruction. . . . Parents and school districts should not expect teachers to pay for equipment and supplies from personal funds, and we should not have to choose between doing them at all" (Liftig 2007, p. 6). I share her concern, but my intent here is not to lecture or opine. Rather, I hope this volume provides a valuable reference at a time when we all need to be resourceful.

To collect all of the articles, books, websites, and organizations that can help you save money is an impossible feat. Not only is there a tremendous quantity of available resources, but the information also changes rapidly and is best pursued through internet searches. Therefore, you will not see lists of websites, grants, and "free" opportunities in this book. Rather, you will find a collection of inspiring articles and book chapters that will provide you and your students with valuable, standards-based learning opportunities that can also serve as springboards to additional investigations. The authors detail untapped resources for materials, reimagined uses for items you already have at home or school, inexpensive workarounds to costly classroom projects, and creative activities that require only free or inexpensive materials.

In addition, many articles and chapters include suggestions for further reading that may expand on the ideas discussed, apply a similar learning tool in a different way, or revise a particular activity for use with different grade ranges. These additional resources are available through the NSTA Science Store (*www.nsta.org/store*), for free or little cost.

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A WORD ABOUT ORGANIZATION

This book comprises five categories, or overarching strategies, for thinking about how to conduct science investigations without spending a great deal of money—either your own funds or those acquired through your district budget.

Student-Created Constructions

When students build their own equipment or create their own models, they have a greater connection to the overall experience, thus enhancing learning. An amazing number of investigations can be developed with a single piece of paper, throwaway items, or dollar-store finds. You already may be familiar with more traditional student constructions, such as paper airplanes, and the lessons they convey. Think how much more students could learn from building roller coasters or paper towers.

Teacher-Created Constructions and Repurposed Materials

Science teachers are great savers of materials. We check out sale bins in stores and rinse out used containers. We collect soda bottles, aluminum cans, shoe boxes, scraps of wood, odd lots of rubber bands, old CDs . . . anything that may possibly be useful in our classrooms. This section suggests ways to put those materials to good use in two general categories: repurposing materials that we have collected and building equipment for student use from free or inexpensive components.

Teaching Strategies That Maximize the Science Budget

There are many ways to reorganize our instructional approaches that enable quality learning to occur at reduced cost. The articles in this section provide suggestions on how to engage students through a variety of strategies. Although the strategies are explained within the context of a specific content area, they can serve as creative inspiration as you consider how to adjust lessons in *any* content area. Creating project materials, playing games, drawing cartoons, developing class newsletters, using learning stations, and tapping into current events all require minimal financial investments but provide enriched experiences for students. Many of these ideas also integrate other subject areas to provide broader curriculum impact.

Instructional Lessons That Maximize the Science Budget

The fourth section offers a collection of life science, Earth science, and physical science and chemistry investigations. They are specific to a given content area but utilize materials that may stimulate ideas for innovative activities with any subject matter. You can use them as they are or modify them to fit your curriculum. Several articles highlight the use of outdoor spaces around your school site that are ideal for scientific investigations.

Funds and Materials

Even after implementing the ideas in this book, you may still have classroom needs that prove too costly to be fulfilled through your budget (or pocket). This section presents suggestions for how to acquire those additional funds.

ADDITIONAL RESOURCES FROM NSTA

In this volume, I have culled some of the most useful NSTA print resources for maximizing your classroom dollars. However, NSTA also provides a variety of free electronic resources that are available for members and nonmembers alike to improve both teaching and learning.

e-Publications

Individual articles from *Science and Children*, *Science Scope*, and *The Science Teacher*, as well as chapters from NSTA Press books, are available in electronic format from NSTA's online Science Store (*www.nsta.org/store*). Many of these—at least two articles per journal issue and one chapter per book—are free to everyone. (The balance of articles is free to NSTA members and available for a small fee to nonmembers.)

Teachers and administrators can also keep up with what's happening in the world of science education by signing up for free weekly and monthly e-mail newsletters (*http://www.nsta.org/publications/enewsletters.aspx*). *NSTA Express* delivers the latest news and information about science education, including legislative updates, weekly. Every month *Science Class* offers teachers theme-based content in the grade band of their choosing—elementary, middle level, or high school. News articles, journal articles from the NSTA archives, and appropriate book content support each theme. *Scientific Principals*, also monthly, provides a science toolbox full of new ideas and practical applications for elementary school principals.

Learning Center

Anyone—teachers, student teachers, principals, or parents—can open a free account at the NSTA Learning Center, a repository of electronic materials to help enhance both content and pedagogical knowledge. By

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creating a personal library, users can easily access, sort, and even share a variety of resources:

Science Objects are free two-hour online, interactive, inquiry-based content modules that help teachers better understand the science content they teach. New objects are continually added, but the wide-ranging list of topics includes forces and motion, the universe, the solar system, energy, coral ecosystems, plate tectonics, the rock cycle, the ocean's effect on weather and climate, and science safety.

SciGuides are online resources that help teachers integrate the web into their classroom instruction. Each guide consists of approximately 100 standards-aligned, web-accessible resources, accompanying lesson plans, teacher vignettes that describe the lessons, and more. Although most SciGuides must be purchased, there is always one available at no charge.

SciPacks combine the content of three to five Science Objects with access to a content expert, a pedagogical component to help teachers understand common student misconceptions, and the chance to pass a final assessment and receive a certificate. Yearlong SciPack subscriptions must also be purchased, but one SciPack is always available for free.

Anyone may participate in a live, 90-minute web seminar for no-cost professional development experiences. Participants interact with renowned experts, NSTA Press authors, scientists, engineers, and other education specialists. Seminar archives are also available on the NSTA website and can be accessed at any time.

Particularly popular web seminars are also offered in smaller pieces as podcasts that can be downloaded and listened to on the go. These 2- to 60-minute portable segments include mini-tutorials on specific content and ideas for classroom activities.

Grants and Awards

NSTA cosponsors the prestigious Toyota Tapestry Grants for Teachers (*www.nsta.org/pd/tapestry*), offering funds to K–12 science teachers for innovative projects that enhance science education in the school or school district. Fifty large grants and at least 20 mini-grants—totaling $550,000—are awarded each year. NSTA also supports nearly 20 other teacher award programs, many of which recognize and fund outstanding classroom programs (*www.nsta.org/about/awards.aspx*).

You may not save hundreds of dollars a year by following the recommendations found in this book. You will, however, find creative ways to keep expenses down and stretch your funds while building student understanding. . . . And perhaps you will be inspired to invent your own low-cost constructions, develop even more inexpensive student activities, find additional uses for everyday items, or uncover a wealth of new resources for obtaining classroom materials.

Reference

Liftig, I. 2007. Never cut corners on safety. *Science Scope* 30 (6): 6–7.

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Chapter 23

Making Mendel's Model Manageable

by Karen Mesmer

Genetics is often a fascinating but difficult subject for middle level students. They can see the results of genes in every organism, but trying to visualize what happens at the level of genes is challenging for concrete thinkers. This activity presents an approach that helps students understand how genotypes can translate into phenotypes. In this lesson, based on the article "Gummi Bear Genetics" (Baker and Thomas 1998), students examine gummi bears and see whether they can determine the genotype for color in three generations of a bear family. Students need to be introduced to the concept of dominant and recessive genes before this activity. Using gummi bears and gummi dolphins gives students an opportunity to solve problems using Mendel's model and then to revise the model when the data do not fit.

Further Reading

- "Toothpick Chromosomes: Simple Manipulatives to Help Students Understand Genetics," from the April 2003 issue of *Science Scope*

GUMMI GENETICS

For the first part of the activity, you will need 43 gummi bears for each group of students in your classroom. The cost for this lab is $15 or less depending on the type of gummi bear that is used. I usually have students work in groups of three, with eight groups per class of 24 students. I use red gummi bears for the dominant color and clear for the recessive color, but any two colors can be used. The gummi bears for each generation of the bear family are put in a small sealable plastic bag labeled with marker as "Parents," "Kids," or "Grandkids." (See Figure 1, p. 110, for exact numbers for each family.) The three small bags are put in a large sealable plastic bag labeled as "Family A," Family B," or "Family C." I also use a marker to label the back of each gummi bear as male (M) or female (F). I cover the label with clear tape so that it isn't rubbed off during the lab. This also keeps students from eating the gummi bears.

To begin this two-day activity, each group selects the bag of gummi bears for Family A. Following the activity sheet, students fill out the number of male and female bears of each color for each generation (see Activity Sheet 1, p. 112). Then they find the ratio of the most common color of bear to the least common. They see, for example, that in Family A,

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the parents are red and clear, but the kids are all red. Students can then deduce, from their previous study of dominant and recessive genes, that red is the dominant color in gummi bears and that clear is recessive. Filling in a Punnett square for each cross (generation 1 to make generation 2, and generation 2 to make generation 3) confirms their solution. It is evidence that the students have solved the problem if the color that they assign to each bear fits correctly in the Punnett square. To gather additional evidence, they need to complete the chart and Punnett squares for Family B and then Family C.

REVISING THE MODEL

Models are often revised in science. If data are found that do not fit an existing model, the model can be added to or changed, or a new model can be developed to replace or coexist with the current model. I use gummi dolphins (or another gummi creature) for the second part of this lab to illustrate codominance.

This lab is set up the same way as the gummi bear lab except that you need 65 dolphins for each group and five different families (see Figure 2). Each generation goes in a small sealable plastic bag and then is put in a larger "family" bag. There will be five families per group and students should only work on one family at a time. I allow them to trade for another family only when they have finished the previous one.

A red dolphin and a yellow dolphin have orange offspring. Students record the same data that they did with the gummi bears and try to determine the inheritance pattern (see Activity Sheet 2, p. 113). They see that it does not fit Mendel's model of simple dominance, because with parents that are two different colors there are three different colors of offspring instead of only two.

A "scientific symposium" convenes at the end of the lab. Students share their ideas about the inheritance patterns in the color of gummi dolphins and critique each other's views based on the data. I have

Figure 1

Bear Families

FAMILY A:
(R,R) crossed with (r,r)
Parents: 1 red male, 1 clear female
Kids: 7 red (3 males, 4 females)
Grandkids: 6 red (3 males, 3 females), 2 clear (1 male, 1 female)

FAMILY B:
(R,r) crossed with (R,r)
Parents: 2 red (1 male, 1 female)
Kids: 7 red (4 males, 3 females), 2 clear (1 male, 1 female)
Grandkids (from a clear female kid and a red male kid): 5 red (2 males, 3 females), 2 clear (2 females)

FAMILY C:
(r,r) crossed with (r,r)
Parents: 2 clear (1 male, 1 female)
Kids: 4 clear (3 males, 1 female)
Grandkids: 6 clear (2 males, 4 females)

Figure 2

Dolphin families

FAMILY A:
Parents: 1 red male, 1 yellow female
Kids: 4 orange (2 males, 2 females)
Grandkids: 2 red (1 male, 1 female), 4 orange (3 males, 1 female), 2 yellow (2 females)

FAMILY B:
Parents: 1 yellow male, 1 yellow female
Kids: 3 yellow (1 male, 2 females)
Grandkids: 5 yellow (3 males, 2 females)

FAMILY C:
Parents: 1 red male, 1 red female
Kids: 5 red (2 males, 3 females)
Grandkids: 4 red (2 males, 2 females)

FAMILY D:
Parents: 1 orange male, 1 yellow female
Kids: 4 orange (3 males, 1 female), 4 yellow (2 males, 2 females)
Grandkids (from an orange male kid and a yellow female kid): 3 orange (2 males, 1 female), 3 yellow (1 male, 2 females)

FAMILY E:
Parents: 1 orange male, 1 red female
Kids: 3 red (2 males, 1 female), 3 orange (1 male, 2 females)
Grandkids (from a red male kid and an orange female kid): 3 red (2 males, 1 female), 3 orange (2 males, 1 female)

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each group present its ideas and the evidence that supports them. Most groups come up with the idea that the two colors blend to get a mix of the colors. We then try to come to consensus as a class as to what is the best idea that takes into account all the data, is realistic, and can be used to make predictions. I make sure students know the current understanding of codominant traits, which is that they produce offspring that are in between the two parents; for example, red and yellow parents produce orange offspring.

CONCLUSION

Research on using modeling suggests that it is an effective approach that provides a framework for students to use both to understand science concepts and to solve problems (Cartier and Stewart 2000). Developing a model gives students a sense of how science works and how data translate into scientific ideas. Being able to use a model to solve novel problems and then to develop a new model to explain anomalous data helps students understand each model better and experience the way real scientists do inquiry. This set of activities takes into account the concrete thinking skills of many middle school students, helping them grasp an abstract idea such as classical genetics.

References

Baker, W., and C. Thomas. 1998. Gummy bear genetics. *The Science Teacher* 65 (8): 25–27.

Cartier, J., and J. Stewart. 2000. Teaching the nature of inquiry: Further development in a high school genetics curriculum. *Science and Education* 9: 247–67.

This article first appeared in the March 2006 issue of Science Scope.

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Activity Sheet 1

Gummi genetics

Procedure

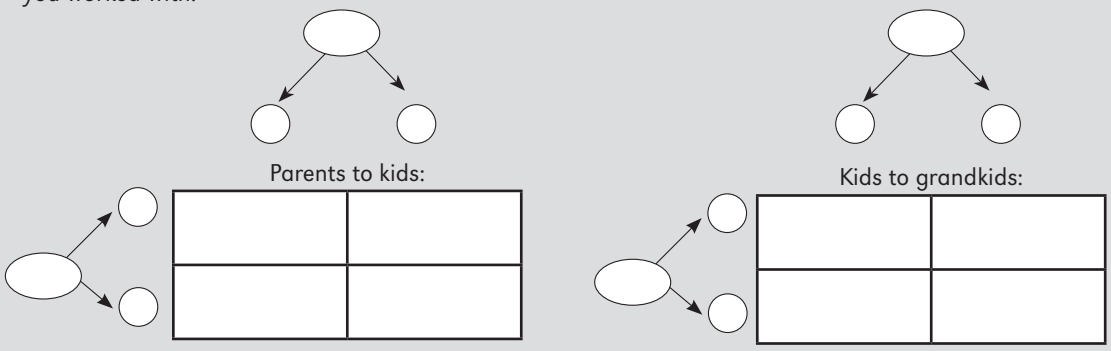
1. Working with your group, get a large bear family bag containing three smaller bags with the gummi bear generations inside. The smaller bags are labeled "Parents," "Kids," and "Grandkids."
2. Empty the contents of only the Parents bag onto the table and record the colors on the chart below. An "M" on the back of the bear indicates that the bear is male. Put the gummi bears back in the bag. These two bears mated to produce the offspring in the Kids bag.

Data chart

Family_____

	Number of red	**Number of clear**	**Ratio of most common color to least common**
Parents	Male = Female =	Male = Female =	
Kids	Male = Female =	Male = Female =	
Grandkids	Male = Female =	Male = Female =	

3. Empty the contents of only the Kids bag onto the table and record the colors on the chart. Put the gummi bears back in the bag. A male and female kid produced the offspring in the Grandkids bag.
4. Empty the contents of only the Grandkids bag onto the table and record the colors on the chart. Put the gummi bears back in the bag.
5. Draw a pedigree for the three generations of the Family you have. Color in any circle or square that has (R, R) genes. Put a dot in the middle of those that are (R, r). Leave blank those that are (r, r).
6. Fill in the Punnett squares below to show how it would be possible to get the results that you did from the family you worked with.



7. Draw a pedigree for the three generations of this bear family.
8. Repeat the procedure (copying a new data chart for each) for the other two bear families.

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Activity Sheet 2

Gummi dolphins

Procedure

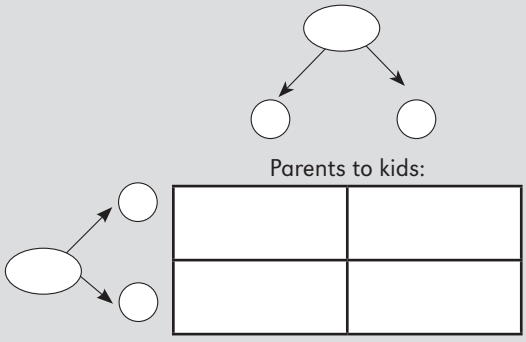
1. Working with your group, get a large dolphin family bag. It will have three small bags of gummi dolphins inside. The smaller bags are labeled "Parents," "Kids," and "Grandkids."
2. Empty the contents of only the Parents bag onto the table and record the colors on the chart. An "M" on the back of the dolphin indicates that the dolphin is male. Put the gummi dolphins back in the bag. These two dolphins mated to produce the offspring in the Kids bag.
3. Empty the contents of only the Kids bag onto the table and record the colors on the chart. An "M" on the back of the dolphin indicates that the dolphin is male. Put the gummi dolphins back in the bag. A Male and Female kid mated and produced the offspring in the Grandkids bag.
4. Empty the contents of only the Grandkids bag onto the table and record the colors on the chart. Put the gummi dolphins back in the bag.

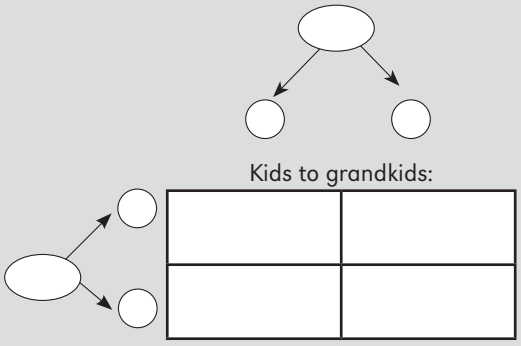
Data chart

Family_____

	Number of red	**Number of clear**	**Ratio of most common color to least common**
Parents	Male = Female =	Male = Female =	
Kids	Male = Female =	Male = Female =	
Grandkids	Male = Female =	Male = Female =	

5. Draw a pedigree for the three generations of the Family you have. Color in any circle or square that has (R, R) genes. Put a dot in the middle of those that are (R, r). Leave blank those that are (r, r).
6. Fill in the Punnett squares below to show how it would be possible to get the results that you did from the family you worked with.





7. Draw a pedigree for the three generations of this dolphin family.
8. Repeat the procedure (copying a new data chart for each) for the four other dolphin families.

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